BIOLOGICALLY INSPIRED FLEXIBLE MATRIX COMPOSITE ACTUATORS

Charles E. Bakis* and Ying Shan
Department of Engineering Science and Mechanics
212 EES Building
The Pennsylvania State University
University Park, Pennsylvania 16802 USA
*cbakis at psu.edu

Flexible matrix composites (FMCs) consist of highly extensible, flexible elastomers reinforced by relatively inextensible, stiff fibers. FMCs modeled after biological structural elements such as muscles and plant cell walls are particularly promising materials for large structural deformation applications. One possible application is to use FMCs to construct thin-wall, cylindrical, pressure-driven actuators. These actuators demonstrate various useful behaviors such as extension, contraction, and twisting when pressurized, depending on the lamination configuration of the FMC membrane. Special interest is given to the contracting type actuator because of the mechanical advantage it provides and its analogy to muscle function. Using a continuum mechanics approach, a finite axisymmetric deformation model is developed to model the behavior of contracting type FMC actuators during pressurization. This new model combines the large deformation membrane theory of Green and Adkins [1] and the large deformation theory for laminated composites by Luo and Taban [2] and is capable of including material nonlinearity and geometric nonlinearity that arise from large deformation and fiber reorientation. The behavior of FMC actuators under various loading conditions are discussed based on the proposed model. It is shown that the contraction-type actuator has a large mechanical advantage. However, there is a trade-off between obtaining a high mechanical advantage and a large contraction strain. Increasing the FMC membrane anisotropy favors both free contraction strain and effective blocked stress in the contracting-type actuator. The contracting actuator is significantly stiffer under constant internal volume conditions than under constant internal pressure conditions, which has important implications for the practicality of active structures based on FMC actuation. Methods to integrate multiple FMC actuators to build interesting active structures are proposed. A finite element model is used to predict the morphing behavior of a plate-shaped active structure for small deformations.

References

[1] J. E. Adkins and R. S. Rivlin, "Large Elastic Deformations of Isotropic Materials—The Deformation of Thin Shells," *Philos. Trans. R.. Soc. London*, 244:505-531, 1952.
[2] S. Y. Luo and F. Taban, "Deformation of Laminated Elastomer Composites," *Rubber. Chem. Technol.*, 72:212-224, 1999.

Keywords: composites, nonlinear deformation